Remarks

Claims 1-70 remain in the application. Claims 1, 31 and 61 have been amended to describe that at least some of the internal supports being attached to one or more of the end walls and at least some of the internal supports being attached to one or more of the sidewalls, the bushing also having linear external supports contacting the bottom of the tip plate, basis found in the specification in Figures 12, 13, and 14 with elements 127, 133, 131 and 130 and the description thereof in the specification on page 23, lines 19-26 and in the paragraph spanning pages 25 and 26. Claims 1, 31 and 61 have also been amended to describe the tips as being arranged in double rows, basis found on page 23, lines 28-31. Claims 2, 32 and 62 have been amended to describe the screen of claims 1, 31 and 61 respectfully as a first screen and to add a second screen laying on top of the first screen, at least some of the holes in the second screen aligning with holes in the first screen and the area of the holes per unit area of the second screen being less than the area of holes per unit area of the first screen, basis for this amendment being found in the paragraph spanning pages 5 and 6 of the specification. Claims 9, 39 and 69 have been amended to describe the screen as the first screen.

Lines 1-10 of page 23 of the specification have been amended to change number 118 to 101 and to change the number 119 to 109, basis for the latter found in Figure 10 and the description thereof and basis for the 101 being Figure 11, the description thereof and that the number 101 has not been used to describe any other element of the bushing.

Line 1 of page 26 has been amended to remove a duplication of element numbers.

Marked up copies of the Replacement Sheets for Figures 9A and 11 showing the changes made and labeled Annotated Sheets are also enclosed in the amendment or remarks section.

The invention of the present claims is a bushing for receiving a molten material and a bushing and method of using the bushing for fiberizing the molten material, such as molten glass, the bushing comprising at least two opposed sidewalls and at least two

opposed end walls, a tip plate having at at least 1600 orifices with at least 1600 hollow tips extending from a lower surface of the tip plate and arranged in double rows, the tip plate being attached to the sidewalls and end walls, the bushing having a boxlike shape having at least four interior corners, an interior support structure comprising a plurality of internal supports welded to a top surface of the tip plate for supporting the tip plate, at least some of the internal supports being attached to one or more of the end walls and at least some of the internal supports being attached to one or more of the sidewalls, and the bushing also having linear external supports contacting the bottom of the tip plate, the support structure forming at least 16 cells located between the bottom of a screen resting on, or mounted very near the top of, the top of the interior support structure. The interior support structure comprises a plurality of intersecting or crossing internal supports with angles between the intersecting supports at each intersection, the internal support structure, in cooperation with the at least one sidewall and the at least one end wall. The screen has a plurality of screen areas containing holes through the screen with a screen area above each of the at least 24 cells formed by the internal support structure. The hole area, per unit screen area, being different in some of the screen areas than in other screen areas to achieve more uniform tip plate temperature profile. Key features of the invention are the presence of a relatively large number of separate cells beneath the screen and then locating the screen of the invention in the bushing such that the bottom of the screen is resting on the top of the support structure, or mounted so close to the top of the support structure that the distance therebetween is less that that at which lateral flow of molten glass from one cell to one or more adjacent cells becomes significant to maintaining optimization of tip plate temperature profile, or is resting on the top of a second, conventional screen that is resting on the top of the support structure. The bushings of the invention advance the art by providing much better control and uniformity of temperature of the molten glass at the tip plate using these key features than had heretofore been possible using the bushings and teachings of the prior art which did not reflect any concern for lateral flow of molten glass beneath the screen.

Figure 11 Replacement Sheet was objected to because the numeral 118 has already been used to identify cells in Figure 9A and 119 was not mentioned in the description. New Replacement Sheets for Figures 9A and 11 are enclosed. The Replacement Sheet for Figure 9A has the number 116 (leadlines to cells) replaced with number 118, basis found in the specification at in the paragraph spanning pages 22 and 23. The Replacement Sheet for Figure 11 replaces 119 (tips) with 109 identifying the tips

(see Fig. 10) and replaces the number 118 with 101 which has not used to describe any other element in the drawings. The paragraph spanning pages 22 and 23 of the specification is amended above in accordance with these changes. A marked up copy of each of the Replacement Sheets (Annotated Sheets) are also enclosed in the Amendments part above to show the changes made. Applicants believe that Figures 9A and 11 are now in compliance with the Rules for drawings and respectfully requests the Examiner to withdraw the objection to the drawings.

Claims 2, 32, and 62 stand rejected under 35USC112, first paragraph, as failing to comply with the written description requirement, the Examiner urging that the specification does not contain basis for "a conventional screen lays on top of a support structure." The Examiners attention is directed to the first full paragraph on page 7 for basis for laying a screen having a non-uniform hole pattern on top of a <u>conventional screen</u>. However, applicants have amended these claims to remove the term "conventional" screen and to define the embodiment described in this first full paragraph of page 7 with embodiments described in the specification in the paragraph spanning pages 5 and 6. Applicants believe that the subject matter of claims 2, 32 and 62 is described in accordance with 35USC112 in the specification as filed, and therefore respectfully requests the Examiner to withdraw this rejection.

Claim 63 stands rejected under 35USC 112, first paragraph, as lacking description because of the term "at least" preceding 4030 tips. Example 1 on page 28 describes a bushing embodiment having about 4800 tips which is a bushing of at least 4030 tips. Further, U.S. Patent Nos. 6,196,029 and 6,453,702, incorporated into the specification by reference, see pages 12, line 18 and page 21, lines 2-3, have basis for "4000 or more tips", see 6,196,029. col. 4, lines 24-25 and 6,453,702, col. 6, lines 35-38. For these reasons applicants believe that the term "at least 4030 tips" does have <u>reasonable descriptive support in the specification</u> and respectfully requests the Examiner to withdraw this rejection. If the Examiner believes that "at least 4030" should be changed to "4000 or more", and upon allowance of the other claims, the Examiner is given the authority by applicants to make such a change by Examiner's Amendment.

Claims 1-70 stand rejected under 35 USC 103 as being unpatentable over Coggin, Jr. '135 in viewof Harris or Stalego and Hanna (EP '225). This rejection is traversed. The Examiner urges that Coggin teaches a bushing having a <u>tip plate</u> and a

screen wherein the entire bottom of the screen rests on top of an interior support structure that cooperates with at least one sidewall and one end wall to form cells between the bottom of the screen and the top of the tip plate, disclosing tips or nozzles extending from a lower surface of a tip plate. Coggin's disclosed bushing that the Examiner uses in the rejection does not have a tip plate with tips or nozzles extending from a lower surface of the orifice plate 38 as apparent in different places in the specification and most particularly lines 24-26 of col. 4, where it is stated, "The undersurface of the orifice plate is planar (i.e. flat) over the entire drawing area 40 and no nozzles or tips protrude therefrom" (emphasis added). Maybe the Examiner confused the nozzles in Fig. 1A with the tips in the claimed bushing, but the nozzle 68 of Fig. 1A in Coggin refers to a bulk gas assembly having the purpose of directing a cooling gas into the array of fibers coming from the orifice plate 38, see col. 6, line 54 through col. 7, line 37. The Examiner may have misunderstood the molten glass meniscuses, the top portion of 10a in Figure 5 as tips, but that is molten glass that forms beneath each orifice in the orifice plate and is pulled into the shape of an inverted cone by the pulling of the fibers from each orifice. Applicants disagree with the Examiner's urging that Coggin, Jr. does not disclose the number of compartments formed by aperatured ribs 44, the orifice plate 38 and the perforated reinforcing plate 46 – Figures 3 and 4 clearly show 6 compartments. The Examiner also stated that Coggins, Jr. did not disclose the number of orifices, or tips, in the orifice plate. Applicants disagree with this statement. Coggins, Jr. repeatedly discloses that his orifice plate is planer on the bottom and does not use tips or nozzles. Also, the Examiner's attention is directed to the Examples in columns 7 and 8 where Coggins, Jr. discloses that the orifice plate contains from 795 to 810 orifices. Further, none of the ribs 44 of the bushings of Coggins, Jr. enter a corner, or contact an end wall of the bushing as clearly shown in Figs. 3 and 7. Therefore, if one of ordinary skill in the art was to modify Coggins, Jr. with the teachings of Harris and Stalego, the presently claimed bushing and method would not be produced!

The Examiner urges that Hanna et al teaches an internal support structure welded to the tip plate of a bushing, the tip plate having at least 1600 tips, the internal support structure comprised of a plurality of intersecting and crossing internal supports to form cells and that it would have been obvious for one of ordinary skill in the art to have utilized the internal support structure of Hanna et al in the bushing of Coggin, Jr. and Harris or Stalego to offer efficient support of the tip plate while encountering hot molten glass, as taught by Hanna et al. This reason for the rejection is respectfully traversed.

First, there is no teaching in Hanna et al, or Coggin, Jr. that would lead one of ordinary skill in the art to use the support structure of Hanna et al in the bushing taught by Coggin, Jr. The bushing orifice plate taught by Coggin, Jr. is extremely small in dimensions and area compared with the tip plates of the bushings taught by Hanna et al. As mentioned above, the bushings of Coggin, Jr. make only 795-810 fibers whereas the bushings of Hanna et al make 1600 or more fibers and up to at least 4030 fibers. The bushings of Coggin, Jr. does not use tips thereby permitting an orifice plate having a much smaller size, e.g. 1.5 x 6.5 inches, than the tip plates of the Hannah et al bushings. The type of bushing disclosed in Coggin is a completely different kind of bushing than the claimed tip plate bushings and the prior art bushings described in col. 1, lines 24-47 of Coggin, Jr. For further evidentiary support of this fact please see the Exhibit A attached herein, containing pages 143-148, particularly the discussion of the "C" process on pages 145-148, of THE MANUFACTURING TECHNOLOGY OF CONTINUOUS GLASS FIBRES by K.L. Loewenstein, published by Elsevier, 1983. This Coggins, Jr. type of flat plate bushing, shown in Fig. V/14 and referred to as "C" process bushing discussed on pages 146 and 148, is not used very much, and when used, is used only for making fibers having diameters exceeding about 14 or16 microns for the reasons described by Loewenstein, i.e. that the bushing is prone to frequent flooding of the glass across the bottom of the orifice plate when a fiber breaks out, resulting in very costly down time and requiring more bushing operators than tip type bushings of the type improved by the claimed invention. Possibly the Examiner did not study this Exhibit as no mention was made of the evidence it contained and the meaning of this evidence to one of ordinary skill as explained by applicants earlier. Bottom line, one of ordinary skill in the art would not consider it obvious to put tips like those used on the prior art bushings that Coggin, JR. refers to on the orifice plate of Coggin, Jr. because to do so would destroy the advantages that Coggin, Jr. teaches for his bushing(s), see col. 1, lines 21-36 and 50-53, col. 2, lines 1-2 and 11-12, col. 4, lines 23-25 and col. 8, lines 19 and 30-35. One of ordinary skill in the art would know from this disclosure and that in the Exhibit A that putting nozzles or tips, for forming fibers, on the orifice plates of a Coggin, Jr. bushing would cause the orifice plate to be greatly increased in area which would destroy all of the advantages of the Coggin, Jr. invention, and also be more complex and costly than using the tip type bushings of the prior art that Coggin, Jr. refers to in col. 1 of this patent. Nor does this Coggin, Jr. patent teach how to make at least 1600 fibers from his bushings.

Also note from the Examples in col. 7-8 of Coggin, that the dimensions of the drawing area, the area of the orifice plate containing orifices, is at most 4.5 x 1.2 inches and that the internal supports (ribs) 44 are spaced on at least 0.7 inch centers. Looking at Figures 4 and 5, there would be a maximum of 6 or 7 cells in the Coggin bushing. Also note that Coggin teaches placing holes, aperatures 52 in the ribs 44 readily permitting "relatively unrestricted flow of molten glass through the ribs 44", permitting "glass to flow freely through the ribs and assures that the segments of the orifice plate between the ribs will be supplied with molten glass, even if a segment of the reinforcing plate should become blocked." By Coggin, Jr.'s own description, this would not meet the limitation of the presently claimed invention.

Second, to further point out that the present invention is directed to tip type bushings, applicants have added that the bushing also has external supports for the tip plate and that the tips are arranged in double rows. Therefore, even if one were to modify Coggin, Jr. with Hanna et al's internal support structure, the presently claimed bushings would not be produced. Further, one of ordinary skill in the fiberizing bushing art would clearly recognize that putting the external supports of the Hanna et al on the Coggin, Jr. bushing would not be practical because it would interfere with the air cooling essential to the operation of the Coggin, Jr. bushing and also it would cause the orifice plate to be substantially increased in width to accommodate the external supports, contrary to the objectives of the Coggin, Jr. invention.

Finally, since the orifice plate of the Coggin, Jr. bushing is so small in dimensions and area, there would be no motivation to one of ordinary skill to complicate and diminish the objectives of the Coggin, Jr. bushings with the internal support structure – nothing in Coggin, Jr. or any other reference reasonably suggests doing so is needed or would be advantageous in any way in the Coggin, Jr. bushings. As clearly shown by Exhibit A, and as repeatedly stated by applicants, the Coggin, Jr. type bushings are a completely different type of bushing than applicants' tip type claimed bushings – the two are as different as apples and oranges, and it would not be obvious to one of ordinary skill in the bushing art to mix the two, and that is clearly not the claimed invention. Given this disclosure, one of ordinary skill in the art would not only not modify Coggin, Jr. in the manner urged by the Examiner, but also would not look to Coggin to improve a tip plate

bushing, and would be led away from the claimed invention if the Coggin teachings were followed.

The Examiner urges that both Harris and Stelago teach a bushing screen having a plurality of screen areas with the hole area per unit area of screen area being different in some areas than in other screen areas and that Stelago additionally teaches that a screen area closest to each bushing corner and end wall has a hole area per unit screen area that is substantially greater than that of the screen areas that are closest to the centerline of the screen. Neither Harris or Stelago teach The Examiner acknowledges that neither Harris or Stelago teach an internal support structure attached to the tip plate, particularly an internal support structure forming at least 16 cells, but that Hanna et al teach such a support structure and that it would have been obvious to have used Hanna et al's support structure in the bushings taught by either Harris or Stalego to achieve better support for the tip plate in these bushings. This rejection, and the potential rejection that it would have been obvious to have used the teachings of either Harris or Stalego re their bushing screens to have modified the bushing screen of Hanna et al such that the hole area in some screen areas above cells is different than hole areas per screen area of other screen areas, are respectfully traversed.

Harris teaches bushings having up to 800 tips receiving solid glass marbles or other solid shapes and for melting the solid glass shapes in a melting chamber 22 in the bushing and on a baffle 24. The baffle 24 has different sized holes therethrough for the purpose of improving the temperature uniformity of the tip plate, but Harris does not teach or reasonably suggest a screen or a baffle that contacts the top of an internal support structure or a screen or baffle of a shape that the entire bottom of the screen or baffle could rest on, or be mounted near, the top of the interior support structure. Harris teaches that when melting glass inside the bushing, the temperature of the molten glass varies substantially more than the molten glass coming into the bushing from a bushing leg of a melting furnace. In the Harris bushing, the bottom of the baffle 24 is located a substantial distance from the top of the tip plate 15. There is no mention or suggestion in Harris of lateral or partially lateral flow of molten glass between the baffle and the tip plate, or how to prevent such flow to achieve the maximum effect of the baffle defined by Harris. Since Hanna et al teaches at col. 8, lines 45-49, that the invention makes bushings having 1600 or more orifices perform in a substantially superior manner, it is unlikely that one of ordinary skill in the art would find it obvious to apply the very

expensive support structure of Hanna et al to the 800 tip bushings taught by Harris. The support structure of Hanna et al is made from alloys of platinum and rhodium, preferably 80% Pt and 20% Rh. The prices/cost of Pt and Rh vary somewhat from time to time, but are always very expensive. For example, the current price of Pt is $1,186 per troy ounce and the cost of Rh is $5,350 per troy ounce. Tip plate sag is not a substantial problem in a 600-800 tip bushing and would not justify so costly an internal support structure.

These same deficiencies exist in the teachings of Stalego, who teaches a bushing that appears to have far fewer tips even than Harris. Also importantly, nothing in Harris or Stalego suggests any need to form cells beneath the screen. The heater strips of Stalego, 30 and 80 are of multiple V shape to provide large surface contact with the glass, see col. 2, lines 43-47 and col. 6, lines 51-54 and there is not teaching or suggestion in Stalego that would lead one to think that this is not an essential feature of the Stalego bushings. Also note that rods 86 in the bushing of Figure 6 do not form cells.

Even if the Examiner should reject on the basis that one of ordinary skill in the art would believe it obvious to use the teachings of Harris or Stalego in the bushings taught by Hanna, there is no basis for such a conclusion, and further, the claimed invention would not be produced, see above, but rather a bushing with a screen that only contacted the support structure at spaced intervals, leaving distances between the bottom of the screen or heater strips and the internal support structure that would allow mixing of the glass coming through the holes in the screen and frustrating the purpose of the claimed invention.

Further, the bushing of Harris does not receive molten material, but rather receives unmelted, solid pieces of glass such as marbles, see col. 2, lines 67-70, and melts the solid glass while the solid pieces of glass lay on the baffle 24. As the glass melts and reaches a sufficiently low viscosity the molten glass flows through the holes in the basket 24 and down into the space above the tip plate 15. Harris teaches that the ends of this bushing tend to be of substantially higher temperature than intermediate portions, see col. 3, lines 21-24 and lines 34-38. One of ordinary skill in the art would recognize that most or all of this situation is the result of the solid glass being introduced through only two inlets 16 that are spaced from the ends of the bushing and that the cold, solid glass therefore cools off the center portion of the bushing to a much greater extent

than the ends. Thus, one of ordinary skill in the art would not look to Harris to improve a much larger bushings that receives molten glass material already at or near or even above fiberizing temperatures. Harris teaches in col. 3, lines 47-59, a higher open area per unit of screen at the end regions of the baffle 24 than the open area per unit of screen area in the center region of the baffle. Having a higher open area per unit of screen area where the glass is the hottest and less open area per unit of screen area where the glass is cooler, as Harris teaches, clearly leads one skilled in the art away from the claimed invention, i.e. Harris teaches using larger holes in the screen in areas that are at the highest temperature, see Fig. 3 and col. 3, lines 47-59. The viscosity of molten glass decreases as the temperature of the molten glass increases and thus in the Harris bushing the flow of hot molten glass through the larger holes in the heater strip near the ends of the bushing would be much greater than the flow of colder glass through smaller holes in the heater strip in the center portion of the bushing thus causing the end portions of the tip plate to be much hotter than the center portion of the tip plate, a result contrary to the objectives of the invention claimed here.

Stalego, Figures 4-5, discloses a bushing for receiving molten glass from a bushing leg, but the heater strip 78 taught is corrugated or a multiple V-shaped configuration to provide substantial area of contact with the molten glass, please see col. 6, lines 35-50. These heater strip configurations taught by Stalego leave substantial distance between all of the holes in the heater strip 78 and the top of the tip plate 15, see Fig. 5, allowing a free lateral or partially lateral flow direction of the molten glass and for mixing of the molten glass coming from the various holes of different diameter, which would frustrate the object of the presently claimed invention, please see the present specification at page 3, lines 25-27 and page 4, lines 12-17. Note that the rods 86 end far above the top surface of the tip plate 66. Nothing in the references cited suggests to one of ordinary skill in this art to modify the bushing of Stalego to produce the bushing structure claimed in this application or the claimed method of making the Stalego bushing. Also, the heater strips disclosed by Stalego have at most 6 areas of screen (Fig. 8) and only 3 areas of different hole size whereas the present invention provides the capability of having at least 24 screen areas capable of having different hole sizes, or other flow control parameters that will much more effectively influence the temperature of the tip plate than the 6 areas taught by Stalego because the entire screen is mounted on or near the support structure.

Also, please see Board of Appeals Decision, Appeal No. 2000-0035, re the reversal of previous rejections of bushing claims containing one or more screens like, or similar, to the screens used in the present invention as being unpatentable under 35 USC 102 as being anticipated by the same Stalego patent cited in this application, and as being unpatentable under 35 USC 103 as being obvious over the teachings of this same Stalego patent. The Examiner urges that this is a separate case, but nevertheless, this Board of Appeals decision is evidence of non-obviousness of the claimed invention.

Given the above differences in the bushings taught by the references and the directions one of ordinary skill in the art is lead by each of these references, applicants further contend that this rejection is an improper hindsight rejection using applicants' own disclosure as a "road map" or "template" to find references the Examiner believes shows the various parts of the claimed invention and then by improperly combining those references to obtain the invention even though one or ordinary skill in the art would not arrive at the claimed invention from the reasonable interpretation of the teachings of those references. Such a rejection is clearly improper as set out in American Medical Systems, Inc. v. Medical Engineering Corp., 26 USPQ 2d 1081, 1091, 1992, or as an instruction manual or template to piece together teachings of prior art to render the claims obvious, see In re Fritch, 23 USPQ 2d 1780, 1783, 1992. Economy of production is as valid a basis for invention as foresight in disclosure of new means and an answer to a long felt want is a valid signpost of invention, see Kaynar Company et al v. The I. Leon Co., Inc., 128 USPQ 25, 27-28, 1960.

For these reasons Applicants believe the present claims are patentable under 35 USC 103 over Coggin, Jr. in view of Harris or Stalego and Hanna et al and respectfully requests the Examiner to withdraw this rejection and to allow all of the claims.

Claims 1, 31, and 61 stand provisionally rejected on the ground of non-statutory obviousness-type double patenting as being unpatentable over claims 1 and 3-4 of Arterburn, 7,194,875 and in view of Coggin, Jr. and Hanna et al. This rejection is traversed for the reasons given above in response to the rejection under 35USC103, Applicants do not believe that the claimed invention is made obvious by the teachings of Coggin, Jr. and Hanna et al. Applicants further contend that this rejection is an improper hindsight rejection using applicants present specification as a "road map" or "template" to

find references the Examiner believes teaches the various parts of the claimed invention and then improperly combining those references to obtain the invention even though one or ordinary skill in the art would not arrive at the claimed invention from the reasonable teachings of those references. For these reasons applicants believe that the claimed invention is not properly subject to an obviousness-type double patenting rejection and respectfully requests the Examiner to withdraw this rejection and to allow all of the claims.

Applicant's attorney believes that the amended claims and arguments above address all of the Examiner's reasons for rejection and that the claims are now in condition for allowance. If the Examiner believes that still further changes are needed, applicant's attorney invites a telephone interview to expedite the disposal of this application.

Respectfully submitted,

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Exhibit A

Glass Science and Technology 6

The Manufacturing Technology of Continuous Glass Fibres

(Second, completely revised edition)

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ELSEVIER
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Bushing frames should be made of non-magnetic material which does not creep significantly at 450°-500°C. Aluminium bronze 5-6 mm thick has been found satisfactory and can be cast into suitable frames. For the direct-melt bushing the frame is of one piece; for marble bushings it is in two pieces, the body and a lid which are bolted together. Frame sections near the nozzles and terminals often distort in use; however, these can be straightened after the bushing is removed at the end of its life, and the frame re-used.

V.2.4. The design of larger bushings

Economic pressure has forced the industry to maintain a constant drive to raise productivity and reduce unit costs. One aspect of this drive is the aim to produce the maximum amount of fibre from a given bushing position, i.e. the bushing and its associated equipment. Since a bushing cannot operate in isolation, a related aspect of this drive has been the development of new types of winders capable of winding rovings direct from one or more bushings, thus not only raising fibre production from a given bushing, but also eliminating a whole production stage.

In this development, the design of bushings of increased throughput has been crucial. Since the direct-roving-winder is limited in the linear drawing speed that it can provide, namely to about 1500 m/minute - which is about one half of that provided by a traditional winder - the bushing must be provided with at least twice the number of nozzles in order to maintain previous production rates.

The industry has done better than that. The problem has been eased by opting to manufacture fibres of the largest possible filament diameter, and diameters of 15 to 20 microns are now common. Bushings of 4800 nozzles are known to be in operation and those with 6000 nozzles cannot be far away. Such bushings, when producing filament of 16 microns, for example, can make rovings (for weaving and winding) of the normal 2400 tex at a rate of about 150 kg/hour.

The larger throughput bushings present major design and operational problems:-

(1) the need to maintain the very large nozzle plate at a uniform temperature;

(2) the need to minimise the distortion of the nozzle plate at

the operating temperature and under the head of glass above the nozzle plate.

The first point can be covered by suitable variation in the metal thickness of various parts of the bushing coupled to major design changes such as placing the terminals horizontally, and by arranging the inlet of the bushing and the outlet of the forehearth in such a way that the glass flows in lamellar flow into the bushing and at the temperature required for fibre forming; thus, the energy supplied to the bushing is minimised, as is the problem of temperature variation of the nozzle plate.

The creep of bushings at elevated temperatures and under the loads normally existing cannot be eliminated. It is possible to use stiffer platinum alloys in whole or in part (see Section V.2.1) but, in any case, extra mechanical stiffening internally and externally becomes necessary. Fig.V/12 shows such an external support; it consists of a stainless steel pipe, water cooled, located longitudinally along the centre line of a bushing with refractory cement between the pipe and the nozzle plate. In addition, extra large and more stiffeners are provided internally across the width of the nozzle plate.

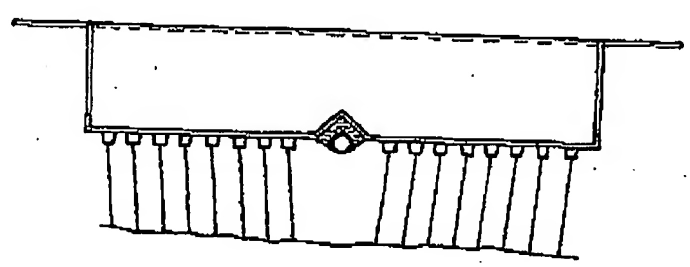

Fig.V/12. External support for large bushing consisting of a water-cooled pipe located centrally and longitudinally under the nozzle plate with refractory cement located between pipe and nozzle plate.

V.2.5. The Strickland-PPG ('Microdyne') and 'C' processes

Provided that there is a supply of glass which exceeds the rate at which fibre can be drawn from a given bushing, the size of the bushing is governed by the number and size of the nozzles or holes and how closely they can be located together in the nozzle or ori-

fice plate.

When comparing the manufacturing technologies of synthetic (organic) polymer fibres with that for glass fibres, a striking difference is the size of the nozzle plate for similar production rates (in terms of volume) between what are, after all, two types of polymers. The differences lie

(1) in the pressurisation of the supply of organic polymer upstream of the spinneret;

(2) the consequent reduction in nozzle (hole) size and closer spacing that this characteristic allows;

(3) the fact that the material of which spinnerets for organic polymers are manufactured are not wetted by the liquid polymer.

In the 'Microdyne' process glass fibres are drawn using techniques derived in concept from those used for organic polymer fibres, but adjusted to make them suitable for glass. The glass supply is pressurised, thus enabling the nozzle or hole diameter for a given throughput to be reduced. In this process holes were substituted for the traditional nozzles and, instead of internal nozzle diameters of $1\frac{1}{2}$ - $2\frac{1}{2}$ mm, holes of $\frac{1}{4}$ mm diameter were needed. These could be spaced so closely that, instead of the 0.1 m² nozzle plate area of the traditional bushing of 400 nozzles, an area of only 100 mm², a reduction of 1/100th, is required in this instance. The bushing became very small indeed (see Fig.V/13).

Despite early promise, this process is still under development. Many reasons for problems can be imagined. Judging by the patent literature they appear to include problems in the removal of gas bubbles from the glass, a problem virtually unknown in normal E glass fibre manufacture, and engineering problems connected with the manufacture and operation of bushings, in one instance even returning to the use of nozzles, and the temperature control and heating of these miniature bushings[c].

From what followed, one can also surmise that the objective may have been over-ambitious. Its successor is a process intermediate in concept. In the 'C' process the extra pressurisation of the glass supply to the bushing is abandoned and the development concentrated on making fibre forming possible from plates containing holes rather than nozzles. The reduction of the length of the cylindrical section of a nozzle to that of a hole through a plate made the hole diameter small when compared to the bore of traditional nozzles and made it possible for them to be placed much more

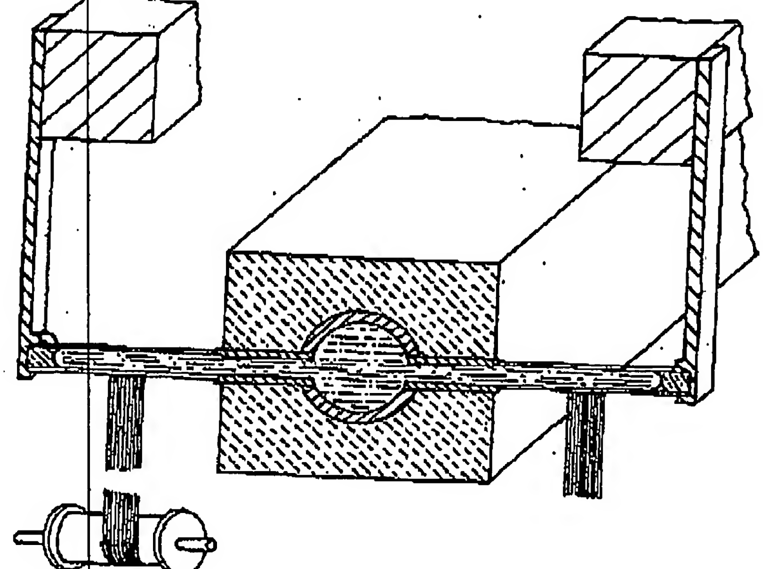

Fig.V/13. The Microdyne Process. Liquid glass under pressure is supplied into electrically-heated pipes, a section of which has been provided with very small holes where the glass is extruded and attenuated.

closely together than is the case with traditional bushings; the saving in the weight of platinum metals is about 70% (see Fig. V/14).

The operating problem associated with the C process bushing is how to overcome and control the tendency of the glass to wet the orifice plate. In the main this is achieved by playing a jet of cold air onto the orifice plate from the underside, thus chilling the menisci of glass and reducing the tendency for liquid glass to flow from one orifice to the next. A supporting technique is, as has already been referred to in Section V.2.1., the use of an alloy that provides the highest possible contact angle with glass. In order to maintain the strength and creep resistance of the orifice plate, it has been suggested that only the outer surface of this plate consists of a thin layer of the special alloy, the rest being

the normal 20% rhodium/platinum alloy: an outer surface alloy of 80% gold/20% palladium has been suggested[7].

This process, while operating and forming fibres, is very productive. In view of the large number of orifices that can be fitted into a comparatively small orifice plate it is particularly suitable for the manufacture of direct-wound rovings for filament winding and weaving. Further improvements in productivity have been achieved by increasing the filament diameter of the fibres drawn. It would appear that all fibre being made by the C process is of 14 micron diameter or above[8].

While progress has been very substantial, one particular problem associated with this process still requires solution. This problem is that if a filament breaks, the glass tends to flow from the orifice where the break occurred to adjacent orifices. Either other fibres can then begin to break or the glass flows into the meniscus of the adjacent orifice making the filament drawn from that orifice twice as heavy per unit length. To avoid this problem, or minimise it, first, the quality of the glass being supplied to the bushing must be maintained at the highest level thus reducing the frequency of filament breaks: second, the operator must be quick to react to a filament break because one filament break can cause adjacent filament breaks and 'flooding' of the orifice plate by molten glass. If flooding does occur extra air jets for cooling the orifice plate must be available and the operator has the laborious task of 'cleaning' the orifice plate by detaching some of the glass adhering to the orifice plate, and then pulling it away sufficiently fast to remove other glass adhering to the plate but leaving glass flowing out of the holes and forming fibres. It is believed that this cleaning operation can take 20 - 30 minutes. This need for 'instant' operator intervention implies rather high staffing levels.

It is difficult to predict how far the C process will penetrate the existing technology, bearing in mind the degree of automation already attained for the older bushing types and the reduction in the number of operators, or cost of labour per unit weight of fibre, that this implies.

V.2.6. Nozzle shields and the stability of the fibre drawing process

The invention of nozzle shields was a major step in increasing the stability and production rates of the fibre-drawing process, as

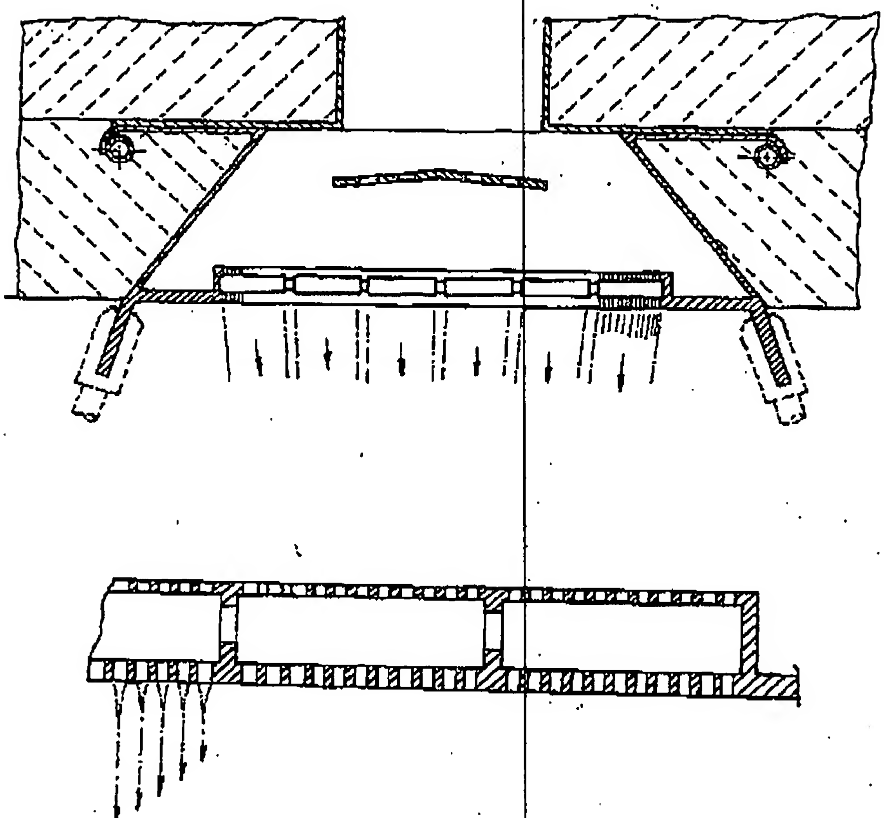

Fig.V/14. A typical bushing according to the 'C-process'. Above, a general view; below, an enlarged view of part of the orifice section. The construction shown, with a perforated plate above the orifice plate proper and connecting members between the two is designed to reduce distortion of the orifice plate. Also note that since the temperature uniformity of the orifice plate is critically important, the bushing terminals are joined at the ori- fice plate horizontally rather than vertically as, for example, shown in Fig.V/8 and 9.